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## Pre-turbo SCR catalyst for NO<sub>x</sub> removal on Ships

**Steen Müller Christensen<sup>a</sup>, Brian Brun Hansen<sup>a</sup>, Keld Johansen<sup>b</sup>, Anker Degn Jensen<sup>a\*</sup>**

<sup>a</sup>DTU Chemical Engineering, Technical University of Denmark (DTU), Kgs. Lyngby, DK-2800, Denmark

<sup>b</sup>Haldor Topsøe A/S, Kgs. Lyngby, DK-2800, Denmark

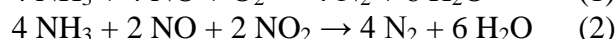
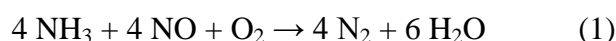
\*Corresponding author: [aj@kt.dtu.dk](mailto:aj@kt.dtu.dk)

*The introduction of MARPOL Annex VI Tier III (1<sup>st</sup> of January 2016) requires approximately 75% NO<sub>x</sub> reduction, compared to present Tier II regulation (from 2011), for new ships when sailing in NECAs. Vanadium based selective catalytic reduction (SCR) of NO<sub>x</sub> is a well-known NO<sub>x</sub> abatement technology for both stationary and mobile applications. However, to achieve the 75% additional NO<sub>x</sub> reduction on 2-stroke marine diesel engines, the catalyst must be placed upstream of the turbocharger, at 300-400 °C but also at high pressures (up to 5 bars). This requires new knowledge on the influence of pressure on the main reactions such as the standard and fast SCR reactions, as well as the effects on side reactions such as unwanted SO<sub>2</sub> oxidation. Therefore this study investigates the effects of pressure on a commercial SCR catalyst to supply optimal and competitive SCR technology solutions for ships.*

### 1. Scope

The 1<sup>st</sup> of January 2016, Marpol Annex VI Tier III was introduced for all new built ships<sup>1</sup>. The agreement forces ship owners to reduce the engine's emission of NO<sub>x</sub> with 75% compared to the earlier Tier II when sailing inside NO<sub>x</sub> Emission Controlled Area's (NECA's).

The high degree of NO<sub>x</sub> reduction can be achieved by either changing the fuel oil into gas powered engines, by using exhaust gas recirculation (EGR) or with subsequent cleaning of the exhaust gas by selective catalytic reduction (SCR) of NO<sub>x</sub>. SCR of NO<sub>x</sub> is a well-known technology for reducing NO<sub>x</sub> and has been applied to both stationary and mobile applications. To reduce NO<sub>x</sub> across the catalyst, a 40% urea in water solution is sprayed into the exhaust gas, in which it decomposes into ammonia<sup>2</sup>. Ammonia reacts with NO<sub>x</sub> across the catalyst at temperatures of 300-400 °C, according to the standard SCR reaction (1) or when NO<sub>2</sub> is present in the exhaust gas, through the substantially faster reaction known as the fast SCR reaction (2)<sup>3</sup>.



More than 500 ships have been equipped with an SCR reactor however, the majority of the installed SCR reactors have been on vessels equipped with 4-stroke engines at which the required temperature is achieved downstream of the turbocharger<sup>4</sup>. The experience with using SCR reactors at 2-stroke engines is, on the other hand, limited. At 2-stroke engines, the SCR reactor must be placed upstream of the turbocharger to achieve the required temperatures (>300 °C), however, also higher pressure will be present. At full load, a large 2-stroke engine can have a pre-turbine pressure of up to 5 bars. The scientific research behind pressurized SCR is scarce and therefore this research elaborates on the possibility of installing pre-turbo SCR reactors at 2-stroke marine diesel engines to achieve IMO Tier III compliance.

### 2. Conclusions

This research outlines the effects of pressure on both the standard and the fast SCR reactions in continuous flow reactors testing vanadium based SCR catalysts. Elevated pressures push the NO to NO<sub>2</sub> equilibrium towards NO<sub>2</sub>, and thereby closer to fast SCR and its increased NO<sub>x</sub> removal rate. Also, side reactions such as the SO<sub>2</sub> oxidation across the catalyst is of importance due to the formation of sulfuric acid and subsequent ammonium sulfate or ammonium bisulfate creating a solid residue on the catalyst itself leading to deactivation or on downstream heat transfer surfaces such as marine boilers, increasing the pressure drop and corroding the boilers. Therefore to ensure reliable and competitive high pressure SCR of NO<sub>x</sub> solutions on ships, more insight is needed on the pressure effects on the catalyst.



## References

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